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SEED BANK ESTIMATES FOR THE McCOWAN ROAD SIMULATED RIGHT-OF-WAY

Report No 88-68-K

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ABSTRACT

Two methods commonly used to estimate the species composition of the buried seed bank were tested at the McCowan road right-of-way site. The methods gave estimates of the seed bank which were considerably different. The relative merits of the 2 methods, and the potential usefulness of a seed bank determination in the planning of the initial vegetation management on a newly established right-of-way, is also discussed.

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34-556-050	834.1	April 11, 1988	88-68-K

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EXECUTIVE SUMMARY

SEED BANK ESTIMATES FOR THE McCOWAN ROAD SIMULATED RIGHT-OF-WAY PROJECT

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The vegetation management techniques used on transmission and distribution rights-of-way must be capable of controlling tall-growing (incompatible) species. Currently, Ontario Hydro uses a selective herbicide application to remove trees and encourage more desirable species to occupy the right-of-way (Niering and Egler 1955, Niering and Goodwin 1974). This in turn should help restrict the establishment and growth of incompatible trees through competition and allelopathic interferences. This is a desirable endpoint. However, the time course for its achievement is quite variable, and highly dependent on the seed bank and propagule sources in each area.

A project was initiated by the Research Division to determine the role of the seed bank in the invasion of the McCowan road right-of-way study site by woody species. This project compares two methods of estimating the composition of the seed bank.

The first technique, termed seedling emergence, involves the incubation of soil samples under controlled, greenhouse conditions. The plants which germinate from the soil are then used as an estimate of the composition of the 'readily-germinable' fraction of the seed bank. This method underestimates the composition of seed bank, however, as many seeds will not germinate under greenhouse conditions due to dormancy and species-specific requirements for germination. This method indicated the seed bank at McCowan Road contained 64 species, at a density of 3851 emergents m^{-2}. No tall shrub or tree species were detected by this method.

The second method, termed seed extraction, involves a physical separation of the seeds from the soil sample via flotation in a salt solution, followed by identification of the seeds. This is a much more rapid procedure, and will provide an accurate estimate of the seed bank, provided a test for seed viability is performed. However, most seeds could not be accurately identified beyond the genus level. The seed bank estimate from this method was considerably different from the seedling emergence method. One hundred and seven different taxa were found and the density was estimated to be 12538 seeds m^{-2}. Eight percent of these seeds were from incompatible trees and tall shrubs.

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A seed bank study may be useful in predicting the potential herbaceous cover on a newly established right-of-way. An estimate of the seed bank prior to the initial clearing and construction of the line will provide an indication of the herbaceous species which will immediately be available to re-vegetate the right-of-way and thus exert a strong influence on the direction of its early development. Comparing the seed bank composition to existing vegetation on rights-of-way which can be considered 'stable' and 'unstable' could provide an early indication of how unstable the new right-of-way will be in the short term. This information may be useful in the design of the initial vegetation control methods.

TABLE OF CONTENTS

1.0	INTRODUCTION		1
2.0	METHODS		2
	2.1	Sample Collection and Preparation	2
	2.2	Seedling Emergence Technique	2
	2.3	Seed Extraction Technique	3
3.0	RESULTS		3
	3.1	Seedling Emergence	3
	3.2	Seed Extraction	3
4.0	DISCUSSION		9
5.0	CONCLUSIONS		12
	REFERENCES		14
	DISTRIBUTION		last page

LIST OF TABLES

		Page
Table 1:	The Composition of the McCowan Road Seed Bank as Determined by the Seed Extraction and Seedling Emergence Techniques	4
Table II:	Summary Comparisons Between the Seed Bank Estimates of the Seed Extraction and Seedling Emergence Studies	8
Table III:	A Comparison of the Plant Groups Estimated by the Seed Extraction and Seedling Emergence Studies	8

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TO: Dr. D. Mills
Director of Research

SEED BANK ESTIMATES FOR THE McCOWAN ROAD SIMULATED RIGHT-OF-WAY

1.0 INTRODUCTION

The presence of trees on a right-of-way represents a continual hazard to the integrity of the lines. To ensure that unexpected power interruptions, caused by woody species coming into contact with the conductors, are minimized, Ontario Hydro undertakes an extensive vegetation control and management program on the 75,000 ha of transmission corridors and 100,000 km of distribution lines under their jurisdiction. The dynamic nature of vegetation, coupled with the rapid growth of many tree species, necessitate retreatment of the rights-of-way with site-dependent cycles ranging from 4 to 8 years, at an annual cost of 10 million and 30 million dollars for the transmission and distribution systems respectively. A considerable savings would be achieved if the treatment cycles could be extended by an additional one or two years through improvements in management techniques.

Methods of vegetation control can be broadly classified into three categories: mechanical, chemical and biological. Currently, Ontario Hydro's primary control policy is a selective chemical treatment of incompatible species. An incompatible tree is a location specific description for any tree which will grow to a height capable of contacting the transmission structures. Chemical control is more effective than mechanical methods in reducing the number of trees over the long term. A mechanical cutting or mowing will remove the problem stems, but may leave the stumps and root system intact. These will produce numerous, fast growing sprouts and suckers which soon cause problems on the rights-of-way (Brown 1987a). Herbicide applications are much more effective at reducing the amount of spouting by killing the root system. However, there is considerable pressure to limit herbicide usage due to off right-of-way movement and possible contamination of surface and ground water (Varfalvy and Sequin 1987, McKinley and Arron 1987).

Although selective herbicide treatments are effective at killing the existing trees, periodic retreatment of the right-of-way is necessary due to invasion by seedlings. It has been hypothesized that a selective control treatment (in contrast to a blanket method) will encourage more desirable, compatible species to occupy the area (Niering and Egler 1955, Niering and Goodwin 1974). These species may in turn help restrict the establishment and growth of incompatible trees through competition and allelopathic interferences, thereby delaying the necessity of re-treatment of the right-of-way.

This is a desirable endpoint, however the time course for its achievement is quite variable, and highly dependent upon the seed and propagule sources in each area. There is currently little information on the source of the seedlings found on the right-of-way. These can already be present on the right-of-way in the form of a seed bank, or originate through either a seed or propagule rain from the surrounding vegetation. Input via the seed rain is restricted to those species in the immediate area, as the distribution of most seeds is limited to a maximum distance of 7 to 400 m (Kellman 1974, McClanahan 1986, Hume and Archibold 1986).

The seed bank will consist of species represented in the standing vegetation as well as several species not present in the area. In general, the seed bank contains more species of previous successional stages than the current vegetational type, and the number of viable seeds in the bank has been observed to decrease as succession progresses towards the climax community (Hayashi and Numata 1971, Kellman 1974, Roberts 1981, Schneider and Sharitz 1986). Therefore, the composition of the seed bank cannot be predicted from the precleared vegetation, but it will have a strong influence on the future vegetation of the right-of-way.

This project was undertaken to assess the importance of the seed bank in the invasion of the McCowan Road simulated right-of-way. Two methods of estimating the seed bank have been compared. The emergence method uses the number of seedlings which germinate from soil samples stored under controlled conditions as an estimate of the seed bank, while the seed extraction method uses a physical isolation of the seeds from the soil samples. The relative advantages and disadvantages of each method, and the possible uses of a seed bank study in the development of the vegetation management program, are discussed.

2.0 METHODS

2.1 Sample Collection and Preparation

The McCowan road right-of-way site consists of a 0.3 hectare (70 x 40 m) section of a woodlot north of towers 58 and 59 of the 500 kV Cherrywood to Clairville transmission corridor. The area was cleared of all incompatible vegetation (consisting of Fraxinus americana (white ash), Acer saccharum (sugar maple), Populus tremuloides (trembling aspen) and Prunus serotina (black cherry)) in the fall of 1984. Five Malus sp. (apple), 12 Crataegus sp. (hawthorn), 3 Ostrya virginiana (ironwood) and 1 Tsuga canadensis (hemlock) of seed bearing age were left on the site. Samples of the soil and humus layers (150 samples of approximately 10 x 10 x 10 cm) were collected across the site at 5 m intervals on November 17, 1986. To simulate a winter stratification, the soils were placed in plastic bags and stored at 5°C for 2 months. The samples were then air dried and passed through a 4 mm mesh sieve to disrupt soil clumps and remove plant debris and roots. They were then divided into two fractions. One fraction, consisting of 150 mL of soil, was reserved for the seed extraction and identification experiment. This was stored in a refrigerator until required. The second fraction, containing 1000 mL of soil, was reserved for the seedling emergence study.

2.2 Seedling Emergence Technique

The 1000 mL soil samples were combined with 500 mL of Promix potting soil and randomly placed on flats in the greenhouse on January 30, 1987. The minimum temperature was maintained at 20°C and natural lighting was supplemented by sodium lamps to provide a 16 h photoperiod. The samples were watered 3 times a week. Seedling emergence was monitored over a 5-month period. Seedlings were removed from the samples as they were identified. Taxonomy was according to Fernald (1950). Nine control flats, containing 500 mL of Promix,

were placed in the greenhouse to monitor possible contamination by other seed sources. No seedlings were found in these flats during the experiment.

2.3 Seed Extraction Technique

Seeds were recovered from the soil using the flotation method of Malone (1967). The soil (100 g) was mixed in a graduated cylinder with a 200 mL solution containing 10 g sodium hexametaphosphate, 5 g sodium bicarbonate and 25 g magnesium sulfate. This was agitated for 2 minutes and the suspension was allowed to settle for 30 minutes. The seeds and other floating organic debris were decanted onto a 125 μm sieve. This procedure was repeated an additional 2 times for each sample. The decanted material was rinsed and air dried. Seeds were removed from this with the aid of a dissecting microscope. Seed identification was according to Montgomery (1977), and aided with comparisons of seeds collected from plants in the field and greenhouse.

3.0 RESULTS

3.1 Seedling Emergence

Although the first seedlings were observed emerging from the soil mixture 3 days after planting, the majority of the plants could not be identified until they flowered. The first flowering was observed near the end of the second month (March 18), and the majority of the plants flowered in the third and fourth months. Seedling emergence was observed in all but 3 samples.

A total of 4,521 seeds germinated in the greenhouse during the 5-month study, representing 53 identified species and 11 unidentified taxa (Table I). This corresponds to an approximate field density of 3851 seedlings m^{-2}, with a mean$\pm$SE of 7.56$\pm$0.24 species per sample (Table II). Eleven species comprised 99% of the seedlings. Verbascum thapsus (common mullein) was the most plentiful species, with 34% (1551 seedlings) of the emergents (Table III). A large number of Solidago sp. (goldenrods) and Aster sp. (asters) represented the second most numerous taxon (25%). Erigeron annuus (daisy fleabane) comprised 8.2% of the emergents, while Rubus idaeus (raspberry) accounted for 5.78%. The most plentiful grass was Festuca capillata (hair fescue), with 132 seedlings, while grasses as a whole included only 5% of the emergents. Medicago lupulina (black medic), Daucus carota (wild carrot), Fragaria virginiana (strawberry), Poa chaixii (broad leaved meadow grass), Trifolium reflexum (buffalo clover) and Cirsium sp. (thistle) were the only other species which comprised more than 1% of the seedlings (Table I). No trees or tall shrub seedlings were observed in the greenhouse emergence study.

3.2 Seed Extraction

All of the samples contained some seeds. Identification of the seeds was difficult due to slight variations in seed size, shape and the loss of characteristic ornaments (barbs, spurs, beaks, pubescens, wings etc.) as the seed aged. One hundred and seven distinct taxa were observed (Table I), but with the exception of Capsella bursa-pastoris (shepherds purse), D. carota, Oenothera biennis (evening primrose), O. virginiana, Oxalis stricta (upright yellow wood sorrel), Rudbeckia hirta (black-eyed susan) and Taraxacum officinale (dandelion), identification may be accurate only to the genus level. A total of 2884 seeds were extracted from the soil samples, corresponding to an approximate density of 12500 seeds m^{-2} with 5.56$\pm$0.24 species per sample (Table II). Ninety-nine per cent of the seeds can be attributed to 22 species.

Table I: The composition of the McCowan road seed bank as determined by the seed extraction and seedling emergence techniques.

Family Species	Common name	Seed Identification Freq.	seed number	estimated seed density (m^{-2})	Seedling Emergence Freq.	seedling number	estimated seedling density (m^{-2})
Asclepiadaceae							
Asclepias verticillata	whorled milkweed	0.65	1	4.3			
Betulaceae							
Ostrya virginiana	ironwood	9.03	23	100.0			
Caprifoliaceae							
Linnaea sp.	twinflower	0.65	3	13.0			
Sambucus canadensis	common elderberry	3.87	8	34.8			
Carophyllaceae							
Cerastium vulgatum	mouse-eared chickweed				10.7	43	37.0
Dianthus armeria	deptford pink	0.65	1	4.3			
Spergularia rubra	sand spurrey	0.65	1	4.3			
Stellaria sp.	stitchwort	1.94	3	13.0			
Chenopiaceae							
Atriplex patula	spreading oranche				3.3	5	4.3
Chenopodium album	lamb's quarters				2.7	12	10.3
Chenopodium rubrum	goosefoot				0.7	1	0.9
Compositae							
Ambrosia artemisiifolia	common ragweed				1.3	4	3.4
Anthemis cotula	dog fennel				0.7	1	0.9
Artemisia vulgaris	white sage	0.65	1	4.3			
Aster sp.	aster	31.61	176	765.2			
Aster ericoides	heath aster	12.26	142	617.4			
Aster novae-angliae	New England aster	7.74	29	126.1			
Aster ptarmicoides	upland white aster	1.29	2	8.7			
Bellis perennis	English daisy	1.29	12	52.2			
Chrysanthemum leucanthemum	Ox-eye daisy				9.3	20	17.2
Cirsium sp.	thistle	12.26	24	104.3			
Cirsium spA	thistle				4.7	8	6.9
Cirsium spB	thistle				17.3	62	53.3
Erigeron annuus	daisy fleabane				64.7	367	315.6
Erigeron canadensis	Canada fleabane				15.3	27	23.2
Erigeron philadelphicus	Philadelphia fleabane	0.65	2	8.7			
Erigeron pulchellus	Robin's plantain	0.65	2	8.7			
Eupatorium perfoliatum	boneset	3.87	7	30.4			
Helianthus divaricatus	woodland sunflower	27.10	70	304.3			
Hieracium aurantiacum	devil's paintbrush	3.87	8	34.8			
Lactuca canadensis	wild lettuce				5.3	10	8.6
Lactuca scariola	prickly lettuce				4.0	8	6.9
Liatris spicata	button-snakeroot	0.65	2	8.7			
Prenanthes racemosa	rattlesnake root	0.65	1	4.3			
Rudbeckia hirta	black-eyed susan	1.29	2	8.7			
Senecio pauperculus	balsam groundsel	1.94	4	17.4			
Solidago caesia	blue-stemed goldenrod	0.65	5	21.7			

Table I (continued)

Solidago canadensis	Canada goldenrod	8.39	93	404.3			
Solidago flexicaulis	zig-zag goldenrod	4.52	10	43.5			
Solidago nemoralis	field goldenrod	0.65	1	4.3			
Solidago gigantea	giant goldenrod				8.7	20	17.2
Solidago sp1.		18.06	149	647.8			
Solidago sp.					92.7	1064	914.9
Solidago sp2.		54.84	668	2904.3			
Solidago rugosa	rough-leaved goldenrod				8.7	16	13.8
Sonchus asper	spiney sow thistle	0.65	1	4.3			
Sonchus oleraceus	common sow thistle				12.0	18	15.5
Taraxacum officinale	dandelion	5.16	10	43.5	10.7	23	19.8
Cornaceae							
Cornus alternifolia	alternate-leaved dogwood	0.65	1	4.3			
Cornus canadensis	bunchberry	7.10	16	69.6			
Cornus racemosa	gray dogwood	5.81	10	43.5			
Cornus sp.	dogwood	1.29	2	8.7			
Cornus stolonifera	red-osier dogwood	2.58	4	17.4			
Cruciferae							
Alliaria officinalis	garlic mustard	0.65	1	4.3			
Capsella bursa-pastoris	shepherds purse	0.65	1	4.3	1.3	2	1.7
Lepidium dulcamara	field peppergrass	1.29	2	8.7			
Thapsus arvense	penney cress				0.7	2	1.7
Cyperaceae							
Carex strigosa	wood sedge				15.3	38	32.7
Cyperaceae sp1.		4.52	19	82.6			
Cyperaceae sp2.		0.65	1	4.3			
Rhynchospora sp.	beaked-rush	0.65	1	4.3			
Ericaceae							
Vaccinium myrtilloides	thin leaved bilberry	0.65	1	4.3			
Fagaceae							
Quercus sp.	oak	0.65	1	4.3			
Geraniaceae							
Geranium maculatum	spotted geranium				3.3	6	5.2
Gramineae							
Festuca capillata	hair fescue				30.7	132	113.5
Gramineae sp1.		0.65	2	8.7			
Panicum capillare	old witchgrass	0.65	1	4.3	7.3	16	13.8
Phleum pratense	Timothy	6.45	18	78.3	3.3	5	4.3
Poa chaixii	broad-leaved meadow grass	24.7	62	53.3			
Poa compressa	Canada bluegrass				4.0	12	10.3
Setaria glauca	yellow foxtail	0.65	1	4.3	0.7	3	2.6
Setaria viridis	green foxtail				0.7	4	3.4
Grass 1		9.03	35	152.2			
Grass 2		3.23	12	52.2			
Grass A					18.0	38	32.7
Grass B					11.3	28	24.1
Labiatae							
Lycopus americanus	cut-leaved bugleweed	5.16	9	39.1			
Prunella vulgaris	self-heal				5.3	10	8.6
Hyssopus officinalis	hyssop	0.65	1	4.3			

Table I (continued)

Leguminosae							
Medicago lupinea	black medic				18.7	116	99.7
Trifolium reflexum	buffalo clover				24.7	56	48.2
Liliaceae							
Trillium grandiflorum	white trillium	0.65	1	4.3			
Lythraceae							
Lythrum salicaria	purple loosestrife	0.65	1	4.3			
Moraceae							
Morus alba	white mulberry	31.61	77	334.8			
Onagraceae							
Circaea canadensis	enchanters nightshade	3.87	7	30.4	9.3	16	13.8
Epilobium angustifolium	fireweed	0.65	1	4.3	2.7	4	3.4
Epilobium latifolium	river beauty	1.29	2	8.7			
Epilobium glandulosum	willow herb				18.0	37	31.8
Oenothera biennis	yellow evening primrose	16.77	71	308.7	16.0	41	35.3
Oenothera parviflora	evening primrose	1.29	4	17.4			
Oenothera serrulata					2.7	6	5.2
Oxalidaceae							
Oxalis acetosella	woodsorrel	1.29	2	8.7			
Oxalis corniculata	creeping woodsorrel				3.3	11	9.5
Oxalis europaea	European woodsorrel				7.3	26	22.4
Oxalis stricta	upright yellow woodsorrel	0.65	1	4.3			
Pinaceae							
Juniperus communis	common juniper	0.65	1	4.3			
Thuja occidentalis	white cedar	1.94	4	17.4			
Plantaginaceae							
Plantago major	common plaintain				4.0	15	12.9
Polygonaceae							
Polygonum sp.		14.84	56	243.5			
Polygonum aviculare	prostrate knotweed	0.65	1	4.3			
Polygonum convolvulus	black bindweed	0.65	4	17.4			
Polygonum hydropiper	water pepper	1.94	31	134.8			
Polygonum natans	water smartweed	0.65	1	4.3			
Polygonum pensylvanicum	pinkweed	0.65	173	752.2			
Polygonum persicaria	ladies thumb	25.16	165	717.4	1.3	4	3.4
Rumex acetosella	sheep sorrel	1.29	2	8.7	0.7	4	3.4
Rumex crispus	curled dock	28.39	113	491.3	6.0	11	9.5
Ranunculaceae							
Actaea alba	white baneberry	2.58	4	17.4			
Ranunculis sp.	buttercup	5.16	9	39.1			
Thalictrum dioicum	early meadow rue				0.7	4	3.4
Rhamnaceae							
Rhamnus cathartica	buckthorn	2.58	4	17.4			
Rosaceae							
Agrimonia sp.	agrimony	1.29	2	8.7			
Aronia sp.	chokeberry	0.65	1	4.3			
Crataegus punctata	hawthorn	14.19	67	291.3			
Fragaria virginiana	strawberry	9.68	20	87.0	19.3	74	63.6
Geum sp.	avens	8.39	21	91.3			
Geum canadense	white avens				0.7	1	0.9

Table I (continued)

Rosaceae (continued)							
Geum vernum	yellow avens				2.0	4	3.4
Potentilla canadensis	dwarf cinquefoil				2.7	4	3.4
Potentilla norvegica	rough cinquefoil	0.65	1	4.3			
Potentilla recta	rough-fruited cinquefoil	0.65	1	4.3			
Potentilla simplex	decumbent five-finger	0.65	4	17.4			
Prunus americana	wild plum	1.29	2	8.7			
Prunus pensylvanica	pin cherry	1.94	4	17.4			
Prunus serotina	black cherry	1.94	4	17.4			
Prunus virginiana	choke cherry	0.65	1	4.3			
Pyrus coronaria	wild crab-apple	0.65	1	4.3			
Rubus sp.	raspberry	30.32	117	508.7	51.3	259	222.7
Rubiacea							
Gallium boreal	northern bedstraw				2.0	5	4.3
Gallium triflorum	3 flowered bedstraw				2.7	9	7.7
Salicaceae							
Salicese sp.	willow or poplar	0.65	1	4.3			
Scrophulariaceae							
Linaria vulgaris	toadflax	2.58	4	17.4			
Verbascum thapsus	common mullein	6.45	20	87.0	93.3	1551	1299.2
Veronica scutellata	march speedwell	1.29	2	8.7			
Veronica sp.	speedwell	0.65	2	8.7			
Solanaceae							
Solanum dulcamara	climbing nightshade	7.10	21	91.3	2.7	4	3.4
Solanum nigrum	black nightshade				0.7	1	0.9
Umbelliferae							
Conium maculatum	poison hemlock	1.94	3	13.0			
Daucus carota	wild carrot	10.32	28	121.7	32.7	112	96.3
Osmorhiza longistylis	sweet cicely	0.65	1	4.3			
Pastinaca sativa	wild parsnip	0.65	2	8.7			
Urticaceae							
Urtica dioica	stinging nettle	0.65	2	8.7			
Violaceae							
Viola sp.	violet	21.29	67	291.3	10.7	42	36.1
Unknown 8		12.90	137	595.7			
Unknown 34		4.52	8	34.8			
Unknown 35		0.65	2	8.7			
Unknown 37		1.29	2	8.7			
Unknown 45		0.65	1	4.3			
Unknown B					4.7	7	6.0
Unknown E					4.7	9	7.7
Unknown I					0.7	1	0.9
Unknown K					0.7	1	0.9
Unknown M					10.0	18	12.9
Unknown O					0.7	1	0.9

Table II: **Summary Comparisons Between the Seed Bank Estimates of the Seed Extraction and Seedling Emergence Studies**

	Seed Extraction	Seedling Emergence
Total number of samples	155	153
Total number of seeds or emergents	2884	4521
Approx. density (seeds or emergents m^{-2})	12538	3851
Total number of species	107	64
Number of species per sample (mean±SE)	5.65±0.24	7.56±0.24
Number of species common to both techniques		16
Number of common species per sample		1.37±0.12

Table III: **A Comparison of the Plant Groups Estimated by the Seed Extraction and Seedling Emergence Studies**

Major species groups	Seed Extraction			Seedling Emergence		
	%	Number	Density (m^{-2})	%	Number	Density (m^{-2})
Aster and Solidago sp.	44	1275	5543	25	1100	937
Graminea	5	131	570	5	238	203
Trees and tall Shrubs[1]	8	231	1004	0	0	0
Verbascum thapsus	1	20	87	34	1551	1299
Polygonaceae	19	546	2374	1	19	16
Other species	23	681	2960	35	1613	1396

[1] Excludes Rubus sp.

Aster sp. and Solidago sp. comprised 44% of the seeds extracted from the soil samples (Table III). Members of the Polygonaceae were the second most numerous family, comprising 19% of the seeds (Table III) (primarily Polygonum pensylvanica (pinkweed), Polygonum persicaria (ladies thumb) and Rumex crispus (curled dock)). Tall shrubs and trees (excluding Rubus sp.) made up 8% of the seeds. Morus alba (white mulberry, 77 seeds), C. punctata (67 seeds), Cornus spp. (dogwood, 33 seeds) and Q. virginiana (23 seeds) were the most numerous species in this tree fraction, while Juniperus communis (juniper), Thuja occidentalis (cedar), Quercus sp. (oak), Rhamnus cathartica (buckthorn), Prunus sp. and a member of the Salicaceae (poplar or willow) were also identified. Other species which comprised more than 1% of the seeds were R. idaeus (5.27%), unknown #8 (6.18%), Q. biennis (3.2%), Helianthus divaricatus (woodland sunflower, 3.15%), Viola sp. (violet, 3.02%), an unidentified grass (1.57%), D. carota (1.26%) and Cirsium sp. (1.08%)

4.0 DISCUSSION

There is a large disparity between the seed bank estimates from the two methods, both in total numbers and species composition. This is especially evident in the relative proportion of Polygonaceae and V. thapsus estimates (Table III). Calculation of a similarity coefficient (S = 2C/(A+B), where A and B are the number of species in each sample, and C is the number of species common to both samples) comparing the seed bank estimates of the two methods for each quadrat produced a mean$\pm$SE similarity of 0.218$\pm$0.019. This is low for a within-sample comparison, considering that comparisons between different samples of the same community are expected to have a similarity coefficient of greater than 0.60 (Gauch 1980, Schneider and Sharitz 1986). Of the 305 taxa identified, only 16 were common to both methods and a mean$\pm$SE of 1.37$\pm$0.12 were common to both estimates of the same soil sample (Table II). The larger sample volume used for the emergent study (1000 ml versus 150 ml) would account for some of this disparity, as the rarer species of the seedling emergence experiments may not have been represented in the seed extractions. However, there were at least an additional 12 species in the seedling emergence study with a sufficient density to be found in the seed extraction (Table I). (This is probably an underestimate, as it assumes 100% germination and survival in the emergence study, which is highly unlikely.)

In contrast, all species identified in the seed extractions should be represented in the soil fractions used in the seedling emergence study. There are several limitations to the seedling emergence method, which leads to an underestimation of the seed bank. The three major limitations are seed dormancy, seed viability and germination conditions.

All dormant seeds require an environmental stimulus to break dormancy. The soil samples were collected in November, and although they were provided with a 2 month cold stratification period, this may not have been sufficient to mimic the winter season. Some seeds require additional manipulations, such as scarification, heat treatments, fluctuating temperatures or light exposures, to induce breakage of dormancy. This may be significant in rights-of-way studies, where an important aspect of the experiment is to obtain estimates for the seed bank of tree species. The fruits of many of these species contain seeds which require a scarification process to break dormancy.

Once this dormancy has been broken, each species will require a specific set of environmental conditions (light, temperature, humidity, photoperiod, and soil moisture) to initiate the germination process. The conditions in the greenhouse will not be favourable to stimulate the germination of all viable, non-dormant seeds. Even when conditions are favourable, seed germination may occur over a lengthy time period. Although Thompson and Grime (1979) report

that incubation periods of 6 weeks may be sufficient to detect the majority of the emergent species, Roberts (1981) has demonstrated that a 2 year germination experiment is required to recover most of the germinable seeds. Thus a seedling emergence study will provide only an estimate of the 'readily-germinable' fraction of the seed bank.

A very rapid examination of the total seed bank can be obtained from the seed extraction method. Eight samples per day could be easily processed with the resources available, thus it was possible to extract all the samples within one month. However, the seed extraction procedure, as used in this study, is also accompanied with several drawbacks. The method uses a salt solution to float the lower density seeds from the higher density soil particles. Seeds more dense than the salt solution will not be recovered. The method is reported to be unsatisfactory at recovering seeds of Ranunculus spp. (buttercups) (Hutchings 1986) and so there is the possibility that other seeds were also excluded. A preliminary investigation using the soil from McCowan road, spiked with Phleum pratensis (timothy) and Pinus resinosa (red pine) seeds, obtained 80-90% recovery for the P. pratensis and 90-100% for P. resinosa. However, Malone (1967) reports that this procedure obtained a near 100% recovery of weed seeds from spiked soil samples, and it is apparent from the density of seeds recovered that the extraction method provided a better estimate of the seeds present in the soil than the seedling emergence method.

The viability of the seeds was not examined and thus the numbers reported in Table I for the seed extraction technique probably represents an overestimation of the viable seed bank. Seed viability may be estimated in several ways: physical examination of the seed, germination tests or staining with tetrazolium salts (Roberts 1981). The tetrazolium test assays for reducing ability in the embryo's mitochondria (Freeland 1976) and thus provides an excellent indication of the health of the embryo. However, it requires the dissection of each seed, which is a very time consuming process when thousands of seeds are involved. Germination tests have the same inherent problems as the seedling emergence study, thus only provide an indication of the non-dormant, readily germinable fraction of the seed bank. A simple physical examination of the seeds, where they are subjectivity categorized as viable or non-viable based on their appearance, will allow for a rapid elimination of many of the non-viable seeds. This may still result in an overestimate of the seed bank, but is preferential to no assessment of viability. Viability estimates were not included in this study, as it was felt that the 8-10 month time lag between the collection of the soil samples and the identification of the seeds was too great to allow for an accurate estimate of the number of viable seeds present at the time of collection.

A major problem also arises in the identification of the seeds. As indicated above, this was very difficult with the resources and expertise currently available. This could be improved if an extensive library of identified seeds were available for comparisons, or if the scope of the study was restricted to a limited number of species.

There have been few studies reported which compare the seedling emergence and seed extraction methods. Johnson and Anderson (1986) used both procedures in a investigation of a tall grass prairie seed bank in Illinois. The techniques provided similar estimates for the total seed density (2000 seeds m^{-2}), but the emergence study counted 45 species as compared to 22 in the seed extraction. This species distribution is opposite to that observed here (Table II), although their seedling emergence study used a much larger portion of the total soil sample collected, which should increase the likelihood of finding rarer species in the emergent study. They also observed a low similarity coefficient (S = 0.49) when comparing the two methods.

The relative ability of the two methods to detect tree and shrub seeds is also quite different. The extraction procedure estimated a density of 1000 seed m^{-2} for this group, while no seedlings were detected in the emergence study (Table III). This discrepancy can also be observed in the literature. Several studies using the seedling emergence technique with soils collected from areas where tree species were common failed to detect them in the seed bank (Livingston and Allessio 1968, Thompson and Grime 1979, Vlahos and Bell 1986). Donelan and Thompson (1980) were only able to detect seedlings of Betula (birch) at 4 sites which had an overstory of Crataegus sp, F. americana, Quercus sp. and Acer pseudoplatanus (sycamore). Moore and Wein (1977) were also able to detect emergents of Betula and Prunus in soil samples from New Brunswick forests. Schneider and Sharitz (1986) estimated a woody seed density of 100-200 emergents m^{-2} on a forested floodplane, while Marquis (1975) found seeds of P. serotina, Acer rubrum, F. americana, Populus sp. and P. pensylvanicum, at a total density of 370 emergents m^{-2} in a Pennsylvania hardwood forest with this technique. A study of a Pennsylvania right-of-way detected 1 A. rubrum emergent on the row (density of 0.3 emergents m^{-2}) while 2 A. rubrum, 2 Sassafras albidum (sassafras) and 1 Populus seedlings were observed in the soil samples from the woodlots adjacent to the row (density of 16 emergents m^{-2})(Hutnik et al. 1987).

The seed extraction procedure appears to be much more promising at detecting the presence of tree species in the seed bank. All studies which used this method on soils collected in wooded areas were able to extract some seeds, although the percentage of viable seeds appear to be extremely low, with densities ranging from 50 to 500 seeds m^{-2} (Olmsted and Curtis 1947, Hayashi and Numata 1971, Kramer and Johnston 1987), compared to the 1000 seeds m^{-2} observed for woody species in this study (Table II).

In general it is considered that the majority of tree and larger shrubs (excluding Rubus spp.) do not contribute to a persistent seed bank (Marquis 1975, Schneider and Sharitz 1986). This appears to be a function of the tree's life history strategy and ecology. Their seeds are relatively large and therefore easily predated. Thus the annual seed production necessary to maintain a large seed bank would require an extremely high energy output. Instead, this energy is channeled into vegetative growth, spreading their reproductive output over several decades. The advantage of maintaining a seed bank is to allow for the rapid recolonization of a gap in the vegetation following a disturbance. As disturbances occur infrequently in forested areas, there is little advantage for a tree to maintain an extensive seed bank (Donelan and Thompson 1980) Recruitment is usually from advance regeneration or the current years seed crop Kellman 1974).

The clearing of the McCowan road site in the fall of 1984 stimulated the germination and establishment of that year's seed crop, as well as those seeds in the seed bank, as indicated by the large number of woody seedlings found on the site in the spring of 1985 (Arron 1985). Continual seedling recruitment during the next two growing seasons would be expected to extensively deplete the remaining seed bank prior to the collection of the soil samples in the fall of 1986. However, the site still appears to have a much larger store of tree and shrub seeds than expected when compared to the above mentioned studies (Olmsted and Curtis 1947, Hayashi and Numata 1971, Kramer and Johnston 1987). This high density suggests that a large number of unviable seeds were detected by the extraction method.

A feature common to most seed bank investigations is the low similarity between the composition of the standing vegetation and that of the seed bank. Although Johnston and Anderson (1986) found a positive correlation between the importance value of species in the vegetation and its occurrence in the seed bank, the seed bank primarily consists of herbs and grasses typical of the early, pioneer stages of community development (Livingston and Allessio 1968, Donelan and Thompson 1980, Vlahos and Bell 1986, Schneider and Sharitz 1986). The

ground cover on most established rights-of-way consists of a mixture of grass and herbaceous vegetation. The seed bank also contains a high percentage of seeds for this type of vegetation (Hutnik et al. 1987), and this may help explain the rapid revegetation of the right-of-way following clearing operations. It is thought that the primary source of woody stems is from vegetative development of stump sprouts and root suckers (Bramble et al. 1984, Dreyer and Niering 1986). The low density of tree and tall shrub seeds observed in this study supports this (Table I, and Hutnik et al. 1987). However, this support may be erroneous, due to the life history strategies discussed above, and the continual pressure applied to the right-of-way by the seed rain from neighbouring trees should not be overlooked. Seedlings and saplings comprise 45% of the incompatible tree stems on the McCowan road site (Brown 1987b) and this will represent a substantial long term problem for rights-of-way management.

A seed bank study may not appear to be suitable for predicting the future invasion of the right-of-way by incompatible tree species. However, such a study could be useful in predicting the potential herbaceous cover on a newly established right-of-way. An estimate of the seed bank made prior to the initial clearing and line construction will provide an indication of the herbaceous species which will be immediately available to invade the right-of-way and thus exert a strong influence on its early development. Comparing the seed bank composition to existing vegetation of rights-of-way which are 'stable' (ie. able to resist invasion by incompatible species) and 'unstable' could provide an indication of how unstable the new right-of-way will be in the short term.

This information may be useful in the design of the initial vegetation control methods. If the seed bank is predominantly loaded with 'unstable' species, it will be a preliminary indication that the right-of-way will require a significant maintenance input in its early life to convert it into the desirable, low maintenance condition. In this case, it may be beneficial to force the vegetation development through the use of cover crops. If the seed bank is comprised of 'stable' species, then less maintenance may be required, and the schedules and type of control can be adjusted accordingly.

The scope of this project was not to estimate the influence of the seed bank on future vegetation, thus it is unknown if the seed bank can be used in a predictive manner, although Moore and Wein (1977) suggest that the buried seed bank can have a large influence on the re-vegetation of an area following clearcutting. Additional studies will be required before the usefulness of this technique to the vegetation control programs can be assessed.

5.0 CONCLUSIONS

1. A seed bank estimate may be useful in estimating the future herbaceous cover on a newly established right-of-way. Additional studies are required to determine the usefulness and application of this information.

2. Both the seed extraction and seedling emergence methods of estimating the seed bank have several drawbacks, and the method of choice will depend on the aims of the study. The seed extraction procedure appears to be better for estimating the seed bank of trees and shrubs.

3. Many tree species of common to middle or late successional stages do not seem to maintain a persistent seed bank. Seedling recruitment in these species will be from the current years seed crop and advance regeneration.

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